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A Research Subsidiary of Cyprus Mines Corporation

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(E74-10018) A RECONNAISSANCE SPACE SENSING INVESTIGATION OF CRUSTAL STRUCTURE FOR A STRIP FROM THE EASTERN SIERRA NEVADA TO (Argus Exploration Co., Los Angeles, Calif.) 19 p HC $3.00 CSCL 08E
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National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Attn: NASA Scientific & Technical Information Facility
ERTS Contracting Officer, Code 245, GSFC
ERTS Technical Officer, Code 430, GSFC
ERTS Project Scientist, Code 650, GSFC
ERTS Scientific Monitor, Code 650, GSFC
J. H. Boeckel, Code 430, GSFC (2 cc.)

Subject: Type I Progress Report, 1 September through 31 October 1973
Proposal - A Reconnaissance Space Sensing Investigation of Crustal Structure for a Strip from the Eastern Sierra Nevada to the Colorado Plateau

Reference: Proposal Control No. SR103
GSFC Principal Investigator ID PRO 15
ERTS-1 Contract NAS5-21809

Gentlemen:

In accordance with Article II, Item 3, and Paragraph 3.1 of the referenced contract, we hereby report the status of our ERTS-1 investigation.

I. Contract Objectives:

A. Analysis, interpretation and evaluation of ERTS-1 data for application to study of regional crustal structure.

B. Comparison and evaluation of selected available remote sensing techniques, including Apollo-9, X-15 and U-2 photography.

C. Field investigation to confirm interpretation studies and evaluate significance and practical applications of geologic phenomena visible in ERTS imagery.

Argus Exploration Company was represented by Mark Liggett at a technical progress review held at Goddard Space Flight Center on Saturday, 27 October 1973. This meeting included discussion with the NASA geology pannel of significant research findings and work in progress.

Additional scientific correspondence has been conducted with other investigators involved in the ERTS-1 or other related remote sensing programs. We have worked with the following scientists in significant exchange of data, research techniques, or interpretation of results:

Dr. Michael P. Kennedy, California Division of Mines and Geology, San Diego, California.

Dr. Alexander Goetz, Jet Propulsion Laboratory, Pasadena, California.

Mr. John E. Carlson, U. S. Geological Survey, Menlo Park, California.

Mr. C. A. Lehnertz, Jr., Phelps Dodge Corporation, Littleton, Colorado.

Mr. E. A. Winter, Phelps Dodge Corporation, Boulder City, Nevada.

Dr. A. K. Baird, Pomona College, Claremont, California.

D. Image Analysis and Enhancement Procedures:

ERTS-1 MSS data analysis and enhancement processing has continued in coordination with field reconnaissance and mapping. Several techniques which we have used are discussed in the Argus Exploration Company Type II report of July 1973. Our standard procedures incorporate the use of a four-channel additive color viewer for analysis of ERTS-1 MSS and other multispectral imagery.

Experimentation is being conducted on enhancement of lithologic and soil color anomalies recorded in ERTS-1 MSS imagery. The technique under investigation is a photographic method for ratioing MSS spectral bands. Encouraging results have been achieved by Dr. Alexander Goetz, J. P. L., in digital computer ratioing of ERTS-1 MSS data. Results of our experimentation will be reviewed with Dr. Goetz.

Production of high-resolution false color composites has been completed over most of the study area. A Report of Investigation accompanying this Progress Report, outlines the procedures used in production of these composites. An abstract of this report appears in Section VII as a Significant Result.

E. Geologic Reconnaissance and Mapping:

The following paragraphs summarize field research topics currently near completion:

Sierra Nevada, California

Field reconnaissance has been conducted along lineaments recognized in ERTS-1 MSS imagery over the southern Sierra Nevada between the Kern River and Owens Valley, Kern and Tulare Counties. The lineaments are expressed in the ERTS-1 imagery as alignments of linear valleys, ridges and other topographic features. Field mapping has indicated consistently poor outcrop exposure along lineaments and ambiguous evidence for their causes. The most consistent associations of features aligned along lineaments are found to be diabase dikes, cataclastic foliation and shearing. A specimen of diabase dike rock is currently undergoing radiometric age date analysis in order to determine the possible relationship of the dikes to late Tertiary and Pleistocene volcanism in the area. A Report of Investigation is currently in preparation.

Lincoln County, Nevada

Additional field work, guided by ERTS-1 data, was conducted in the region between the southern Pahroc Range and the Delamar Mountains, Lincoln County, Nevada. The work was undertaken in an attempt to understand the relationship of Basin-Range faulting to a local zone strike-slip displacement.

Field work in the area around and south of Delamar Lake supports the interpretation of left-lateral strike-slip movement along several northeast trending fault zones. This strike-slip deformation does not continue northeastward into the Delamar Mountains beyond Gregerson Basin and is believed to be contemporaneous with late Tertiary range-front faulting. A Report of Investigation is in preparation.

Esmeralda County, Nevada

Fixed-wing aerial reconnaissance was conducted in support of field mapping in northern Fish Lake Valley, Nevada, and the Paymaster Canyon-Lida Wash area east of the town of Silver Peak, Nevada. During this overflight, 35mm Ektachrome and Ektachrome Infrared photographs were taken for comparison with ERTS-1 MSS false-color composites.

This aerial support completed research in the area. A report on a major normal fault in the Paymaster Canyon area is summarized under significant results in Section VII of this report.

Regional Patterns of Cenozoic Volcanism

A map compilation (1:1,000,000 scale) and supporting data have been assembled in order to study the distribution, age, petrographic characteristics and possible structural controls of Tertiary volcanic and igneous centers within the southern Basin-Range Province. Although many of the volcanic centers in the study area have been previously mapped and discussed in published literature, recognition of regional patterns has not been emphasized. The use of ERTS-1 data in study of regional structural relationships has important potential in exploration for mineral resources or possible sources of geothermal energy, known to be spatially associated with volcanic centers in the study area.

IV. Conformance to Work Schedule and Recommended Changes in Operation:

Most phases of the Argus Exploration Company ERTS-1 research program are currently on schedule in accordance with the Network Schedule of April 1973 and Data Analysis Plan of 4 December 1972.

The Argus ERTS-1 research project is currently fully staffed permitting concentration on several critical tasks of the program. Certain research tasks have been delayed for administrative reasons but major setbacks in research are not anticipated. No changes in operation are recommended over the Data Analysis Plan of December 1972 or the Network Schedule of April 1973.

V. Funding Status:

As indicated in Financial Reports 533 Q and 533 M dated 24 October 1973 and in Report 533 M dated 14 September 1973, proposed project funding will be sufficient to complete the contracted research program.

VI. Analysis of Research Progress:

Through the period covered by this Progress Report, emphasis has been on confirmation of anomalous structural relationships interpreted from the ERTS-1 and subsidiary remote sensing data. This focus on "field problems" has included relatively detailed study of key areas in order to assess the types of geologic phenomena uniquely visible or more effectively studied in the ERTS-1 data.

In accordance with our Data Analysis Plan, we are now beginning a phase of research in which the focus is shifted to a regional synthesis of data compiled across our study area. Primary emphasis is being placed on the study of the regional structural or lithologic relationships of known mineralization, geothermal springs, and recorded earthquake epicenters.

VII. Significant Results:

The following abstracts outline significant results of the Argus Exploration Company ERTS-1 investigation:

<u>False-Color Compositing of ERTS-1 MSS Imagery</u>

Wally MacGalliard and Mark Liggett
Argus Exploration Company
Los Angeles, California 90071

ABSTRACT

An operational technique for producing high-resolution false-color composites of ERTS-1 Multispectral Scanner (MSS) imagery has been developed for use in a typical photographic laboratory equipped for color processing and printing. The technique uses standard NASA (NDPF) or EROS black/white data products, and permits a broad range of control on composite color balance and contrast range. The use of an additive color viewer has proven valuable for determining the optimum color balance of composites for effective interpretation. The compositing technique is adaptable to data from a variety of multispectral imaging systems, including multi-seasonal and multi-polarization data.

A Report of Investigation on the procedure discussed in the abstract accompanies this Progress Report.

VIII. Work Planned for the Next Reporting Period:

A. Geologic Field Reconnaissance:

A portion of the next reporting period will be spent in completing reports of research near completion, as summarized in Section III-E. The primary focus of research during this next reporting period will be study of regional associations of structural patterns with the distribution of known volcanic and igneous centers, known mineral deposits and geothermal springs, and recorded earthquake epicenters. This study will include analysis of ERTS-1 MSS spectral signatures related to key lithologic or soil anomalies associated with the above phenomena.

B. Image Analysis and Enhancement Procedures:

Current experimentation will continue with techniques for enhancement of ERTS-1 MSS and subsidiary remote sensing data. Investigation will continue on MSS spectral band ratioing as outlined in Section III-D. Additional research will be conducted on photographic edge enhancement and directional pattern filtering.

C. Data Source Research:

We will continue to accumulate and index pertinent reference material on key areas within the Test Site. Final map compilations are in preparation for the distribution of known mineral deposits, recorded earthquake epicenters, and geothermal springs within the site.

IX. Authorized Reports and Publications:

Reports of Investigation accompanying this report are cited in Significant Results, Section VII.

X. Changes in NDPF Standing Order Form:

No changes have been made in our Standing Order Form of 18 October 1972. Routine ERTS-1 MSS coverage was terminated as of July 1973 as originally proposed.

XI. NASA Data Requests:

Retrospective requests were placed for 9" x 9" transparencies of ERTS-1 MSS Frames #032-17373 and #9-17432 on 10 September 1973.

APPROVED:

William E. Hosken, President

FALSE-COLOR COMPOSITING OF ERTS-1 MSS IMAGERY

Argus Exploration Company
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November 1973
Report of Investigation

Prepared for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

Approved by

W. E. Hosken
President

A MAJOR NORMAL FAULT IN ESMERALDA COUNTY, NEVADA

John F. Childs
Argus Exploration Company
Los Angeles, California 90071

ABSTRACT

A 50 mile north-trending linear anomaly recognized in ERTS-1 MSS imagery west of Goldfield, Nevada has been confirmed as a steeply west-dipping normal fault, here termed the Paymaster Fault. This structure trends southward from the General Thomas Hills along Paymaster Valley and the east side of Clayton Valley into the Palmetto Mountains. There, it terminates against a less pronounced east-trending transverse anomaly which is also believed to be fault controlled. The Paymaster Fault is the most prominent of several large normal faults which terminate southward against this transverse anomaly.

DISCUSSION

The Paymaster Fault in southwestern Nevada is a prominent linear feature in ERTS-1 imagery extending approximately north-south for 50 miles (Figures 2 and 3). The fault is shown on the preliminary map of Esmeralda County (Albers & Stewart, 1965) in a generalized tectonic inset map but is not included in the geological map. The inset map shows the Paymaster Fault extending southward along Paymaster Valley into Clayton Valley and from there turning westward toward the Silver Peak Range. ERTS-1 and U-2 imagery of the area suggests that the Paymaster Fault, rather than turning westward, continues southward along the east side of Clayton Valley and along Lida Wash into the Palmetto Mountains northwest of the town of Lida, Nevada (Figures 2 and 3). This interpretation was confirmed by field reconnaissance.

The Paymaster Fault is a steeply west-dipping to vertical normal fault, with probable vertical displacement of at least 1000 feet along some segments. Scarps in alluvium northwest of the General Thomas Hills suggest a Quaternary age for at least some of the movement. A large, nearly vertical east-trending fault intersects the Paymaster Fault in the General Thomas Hills. This fault is probably older than the Paymaster Fault because it does not cut Recent alluvium and appears to be offset by the Paymaster Fault.

False-Color Compositing of ERTS-1 MSS Imagery

Wally MacGalliard* and Mark Liggett
Argus Exploration Company
Los Angeles, California 90071

ABSTRACT

An operational technique for producing high-resolution false-color composites of ERTS-1 Multispectral Scanner (MSS) imagery has been developed for use in a typical photographic laboratory equipped for color processing and printing. The technique uses standard NASA (NDPF) or EROS black/white data products, and permits a broad range of control on composite color balance and contrast range. The use of an additive color viewer has proven valuable for determining the optimum color balance of composites for effective interpretation. The compositing technique is adaptable to data from a variety of multispectral imaging systems, including multi-seasonal and multi-polarization data.

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The Paymaster Fault is extrapolated southward along the east side of Clayton Valley (Figure 3). Several escarpments, thought to be paleo-shorelines occur in the alluvium along this segment. However, bedded alluvium east of these features is tilted eastward, suggesting that the straight paleoshorelines may be fault controlled.

Range front faulting is evident along the eastern side of Clayton Valley. Numerous faults cutting Tertiary pumice breccias and the underlying granitic rocks were studied in detail in the area indicated by an arrow in Figure 3. The results of this study are summarized in Figure 4. This fault zone can be traced in the ERTS-1 imagery southward along the west face of Clayton Ridge. From the south end of Clayton Ridge, the zone is extrapolated 1/2 mile across alluvium into an andesite sequence near the mouth of Lida Wash. The total amount of movement on individual strands of the fault zone in the andesites is small. Strands of the zone continue along the walls of Lida Wash Canyon for approximately four miles southward into the Palmetto Mountains, where evidence of faulting is found in the offset of lithologic units across the canyon, and in discontinuous zones of faulting and alteration within the canyon.

The Paymaster Fault appears on the ground and in ERTS-1 imagery to terminate southward against a broad east-west trending topographic depression which is probably fault controlled (Figure 2). This transverse zone, here called the Palmetto Zone, extends discontinuously westward from Mount Jackson Ridge to Fish Lake Valley, a distance of approximately 30 miles. The Palmetto Zone appears to be an important structural feature of this region since it also forms the southern terminus of several large normal faults in the Goldfield Hills southeast of Goldfield, Nevada.

CONCLUSIONS

The Paymaster Fault is clearly apparent in ERTS-1 MSS imagery as a prominent north-trending lineament. This fault, unlike most Basin-Range normal faults, is not restricted to a single range and can be traced for 50 miles as a sharp, straight zone along or within three ranges.

REFERENCES

Albers, John P. and Stewart, John H., 1965, Preliminary Geologic Map of Esmeralda County, Nevada: U. S. Geol. Surv. Mineral Investigations Field Studies Map MF-298.

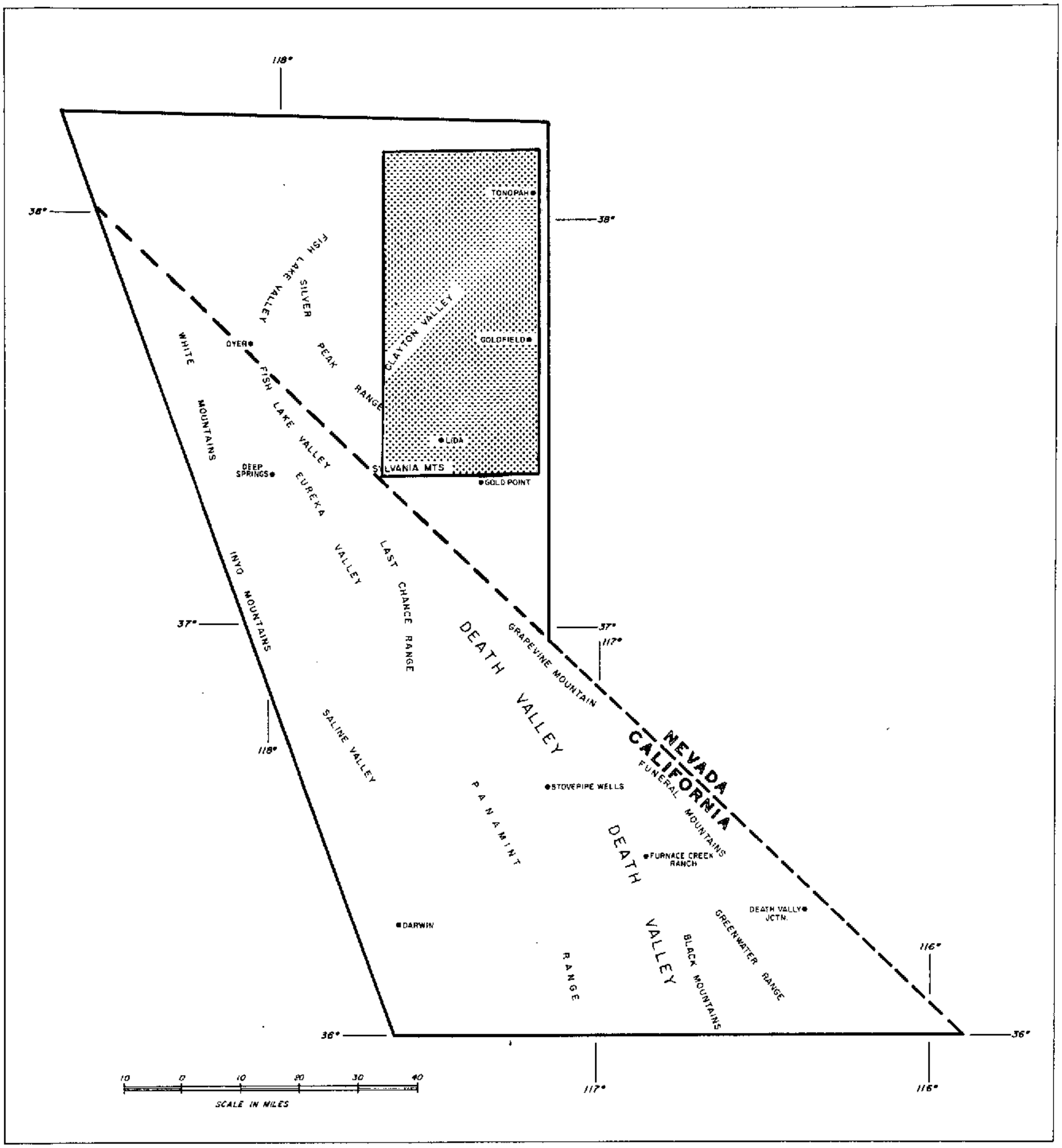

Figure 1 - Index map of the study area in southwestern Nevada. The area covered in Figure 3 is shaded.

Figure 2 - Enlarged portion of ERTS-1 MSS Frame 1144-18010, Band 7, 14 December 1972. The area covered in this enlargement is approximately the same as in Figure 3.

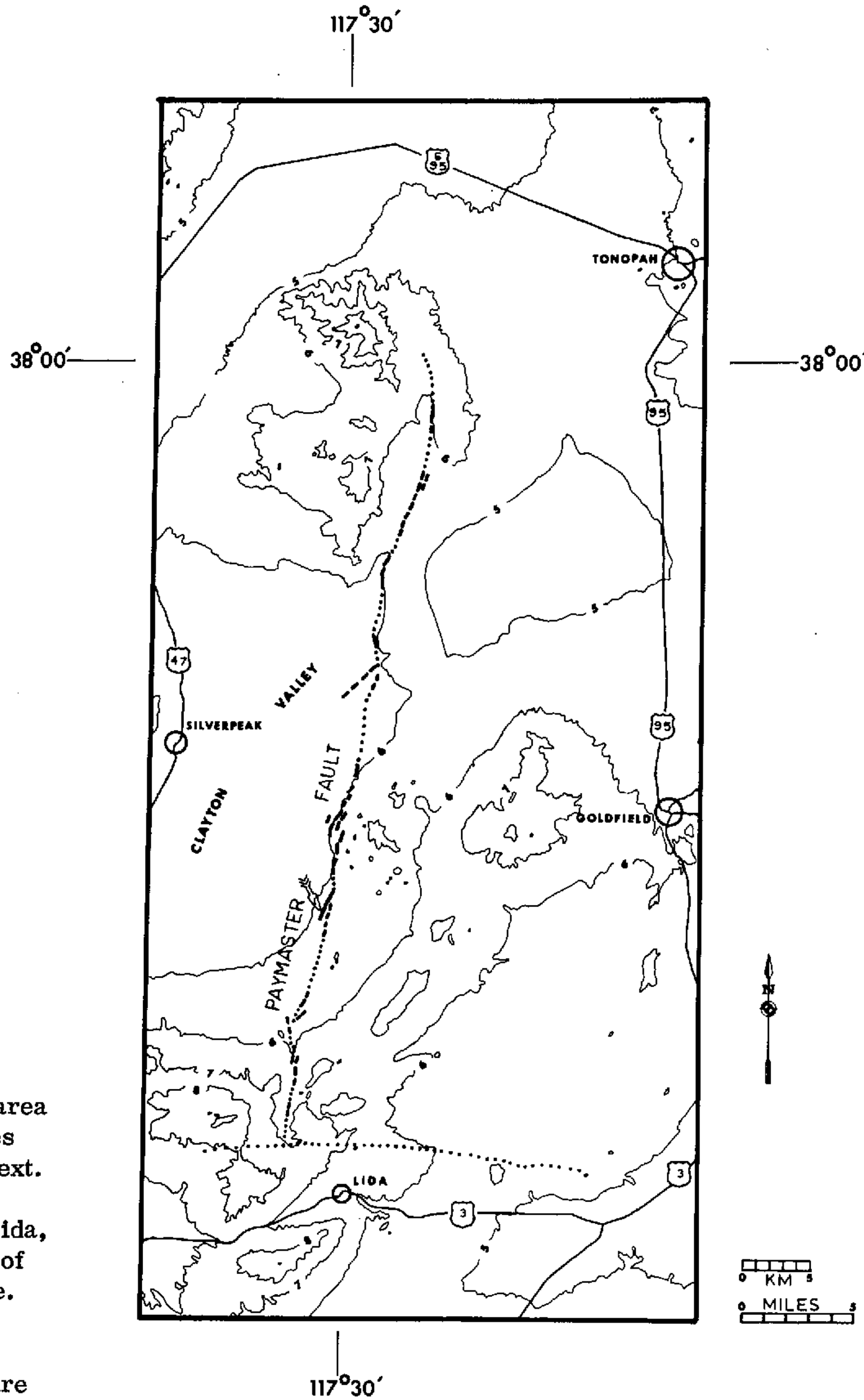

Figure 3 -

Map of the study area showing structures described in the text. Dotted east-west feature north of Lida, Nev. is a portion of the Palmetto Zone. Contours are in thousands of feet. Base maps used are the Goldfield and Tonopah 1:250,000 topographic maps.

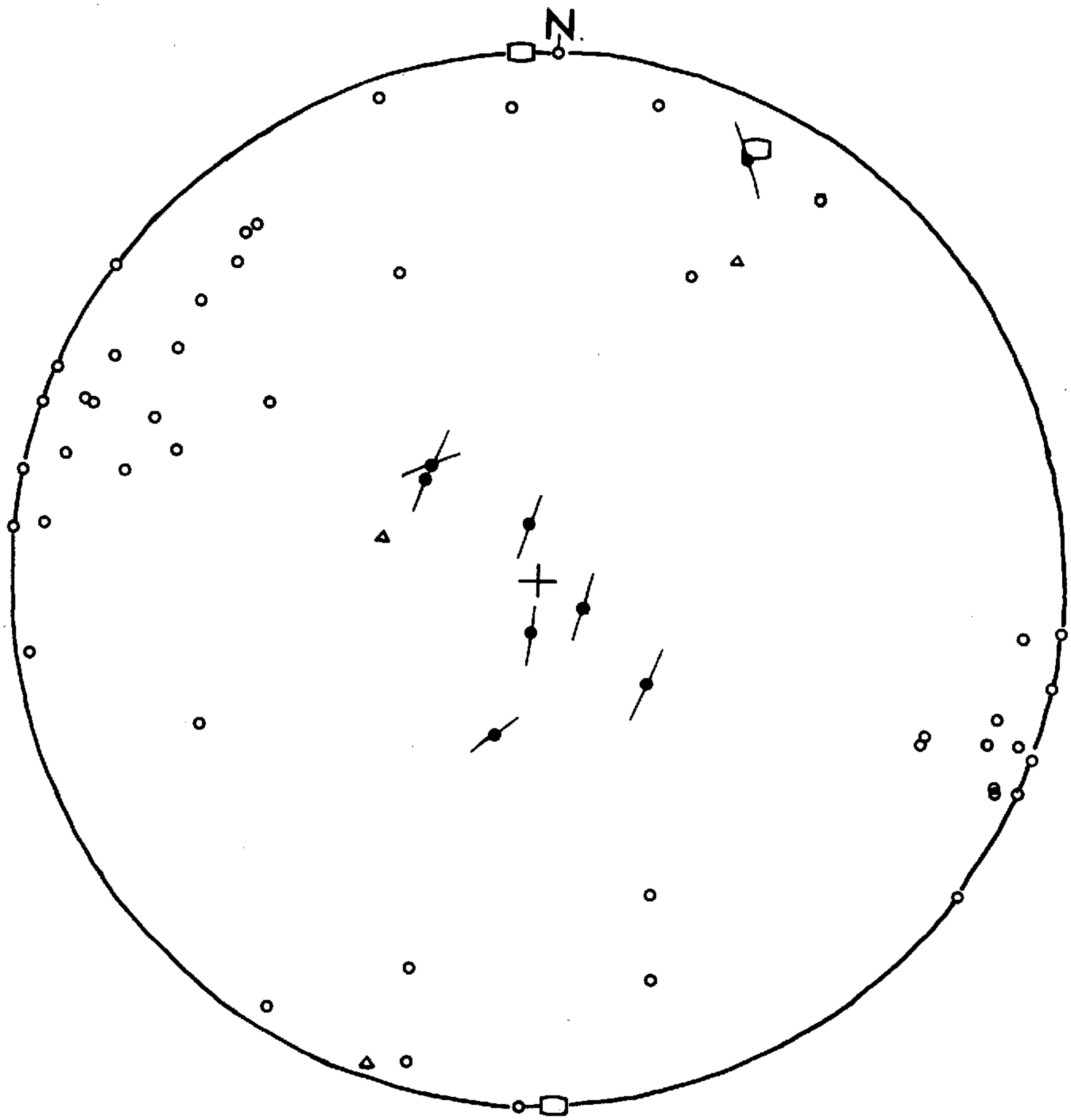

Figure 4 - Equal area lower hemisphere projection of slickensides (closed circles) and part of fault planes on which they lie (arcs), faults (open circles), bedding (triangles) and dikes (rectangles). Structural data from area indicated by arrow in Figure 3.

INTRODUCTION

The following technique was developed as part of an investigation of geologic applications of ERTS-1 Multispectral Scanner (MSS) imagery. An important advantage of multispectral imaging is the ability to study the varied information recorded in each spectral band of the imaging system. These variations are due primarily to differences in the reflectance characteristics of features such as rock or soil units, and vegetation types, vigor or seasonal variation.

In the ERTS-1 MSS system, four images are recorded over the following spectral ranges:

ERTS-1 Band No.	Spectral Range	Description
4	.5-.6 microns	Green and yellow
5	.6-.7 microns	Red
6	.7-.8 microns	Near-infrared
7	.8-1.1 microns	Near-infrared

An important tool for analysis and interpretation of multispectral imagery is additive color viewing, which permits reconstruction of "natural" or "false" color images by combining the spectral bands, each with an appropriate color filter. Additive color viewing also allows the "real time" manipulation of color balance by variation of the band/filter combinations and illumination intensities for each channel. This flexibility in color balance permits more effective interpretation of the multispectral imagery than is possible with the fixed color balance of polyemulsion films or standardized multispectral composites. The principles of additive color imaging are outlined in a number of publications, for example Yost and Wenderoth (1968), and Ross (1973).

In order to most effectively use the ERTS-1 MSS imagery, the following technique was developed for reproducing the optimum color balance as determined by analysis of the MSS imagery on an additive color viewer. The compositing procedure uses standard 70mm or 9" x 9" ERTS-1 MSS positive transparencies as distributed by the NASA Data Processing Facility (NDPF), Goddard Space Flight Center, Greenbelt, Maryland and the EROS Data Center, Sioux Falls, South Dakota.

REGISTRATION

Registration equipment consists of a Master film punch[1] and 1/4" diameter Berkey pins[2]. The pins are positioned on a light table, a negative carrier and a vacuum

[1]Master Products Manufacturing Co., 3481 E. 14th St., Los Angeles, Calif. 90023
[2]Berkey-Alldis Register Products, Berkey Technical Companies, Inc., 25-15 50th St., Woodside, Long Island, N.Y. 11377

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printing easel. They are set on 3 1/2" centers for projecting 70mm transparencies onto 5" film, and 7" centers for contact printing 9" x 9" transparencies onto 10" film.

To prepare three 9" x 9" multispectral positive transparencies for contact exposure, the transparencies are first rough registered on a light table, one over the other, and one edge of the set cut uniformly with a straight-edge and mat knife. This facilitates butt taping of the transparencies to leader strips without overlap. The leader strips are 1 1/4" x 9" pre-punched blank films of the same thickness as the positive transparencies.

The first leader is placed over the pins on the light table and a 9" x 9" transparency taped to it, emulsion side down. The tape used is Scotch Brand Polyester Film Tape No. 850. The second leader is then placed on the pins over the first transparency and a second transparency is manually registered with the first. This is done by placing a thin glass plate over the pair to insure image contact, and viewing the corner cross-hairs and edge-identification through a 5X achromatic magnifier. When perfect registration has been achieved, the second transparency is taped to its leader and removed from the pins. Successive positive transparencies are registered and taped in the same manner. In order to facilitate this task, it is often most effective to use the highest contrast transparency, generally Bands 6 or 7, as the master against which the other bands are registered.

The registration procedure for a set of 70mm is the same, except for the smaller size which makes the visual work more tedious. Frequently, however, the ERTS-1 MSS 70mm transparencies surpass the 9" x 9" transparencies in resolution, and are well worth the extra effort required for registration.

TRI-COLOR EXPOSURE

An 8" x 10" Durst Condenser enlarger[3] is used as a light source to produce inter-negatives by either contact printing or projection. It is equipped with a 500 watt Opal bulb, a filter wheel containing the standard Wratten tri-filter set (Red No. 29, Green No. 61, and Blue No. 47b, process type lenses, and a vacuum easel fitted with pins for registration of various film sizes.

To contact print a set of 9" x 9" transparencies, a sheet of Ektacolor Internegative film, Type 6110, is first punched in the dark and placed on the pins of the vacuum easel, emulsion up. A pre-punched transparency is registered over the film, emulsion down, and exposed using the suitable tri-color filter. It is then removed, replaced by the second transparency and exposed using a second tri-color filter, and so on.

To project a set of 70mm transparencies, the procedure is the same, except that the smaller transparencies are pin registered within a glass negative carrier and projected to the desired size on the easel.

[3]Durst (U.S.A.) Inc., 623 Stewart Ave., Garden City, N.Y. 11533

For each set of MSS transparencies, the proper tri-color exposures are determined by test. The objective is to retain as much of the original image density range as possible, and to duplicate the desired color balance. The color balance is controlled as a function of the relative differences in exposure times for the separate MSS bands. However, several other variables should also be considered in test exposures, including differences in density range between and sometimes within sets of MSS transparencies, and filter factors required for different batches of inter-negative stock. The actual exposures will, therefore, differ between photographic labs. The exposure times currently in use at this facility are: Red-12 seconds, Green-40 seconds, and Blue-18 seconds. Lense apertures are typically varied between f:11 and f:16 as determined by densitometer readings of the MSS transparencies.

Exposure values can be split between two bands if necessary; for instance, Bands 6 and 7 may be combined in a composite both with red illumination. Other variations in exposure intensity and time can be made within the reciprocity range of the internegative film.

DEVELOPMENT

Ektacolor inter-negative films are developed to normal gamma using standard Eastman Kodak C-22 chemistry.

PRINTING

Inter-negatives are printed on Ektacolor RC paper, N surface. Prints up to 16" x 20" are processed by batch in a Calumet processor, using Ektaprint 3-sol. chemistry. Prints to 30" x 40" are processed one at a time in a Kodak 30 A processor.

When using a balanced inter-negative, a test print should have a neutral gray scale, extending from off-white to black. This then is a technically accurate composite, which is normally the objective of color separation work. However, in printing false-color composites for maximum interpretive value, subjective judgments take priority and the gray scale is typically shifted from neutral toward a yellow, orange or red balance by 10 to 20 units of filtration. By test printing with varied filtration, subtle shifts in color balance can be precisely controlled.

CONCLUSION

Because of the broad control of composite color balance and contrast range, the procedure outlined above has proven effective for detailed analysis and interpretation of ERTS-1 MSS imagery. Enlargements having excellent resolution up to 30" x 30" have been made from the standard NASA data products.

The details of equipment and development processes outlined here are intended only as a guide for initial experimentation. Specific procedures can be easily modified depending upon available laboratory equipment and final imagery requirements. A variety of image enhancement procedures can be performed at various steps during compositing. Some procedures, such as manipulation of image contrast range, highlight masking, or density slicing can be most easily performed on the individual black/white MSS transparencies prior to color compositing. These enhanced transparencies can be analysed by additive color viewing to guide optimum choice of color balance.

In addition to false color analysis of conventional multispectral imagery, the technique can be applied to a wide range of multiple imaging systems as long as suitable registration can be achieved. Examples are multi-seasonal ERTS-1 imagery, cross-polarized SLAR imagery, and diurnal variation of thermal infrared data.

References

Ross, Donald S., 1973, Simple multispectral photography and additive color viewing: Photogrammetric Engineering, Journal of the American Society of Photogrammetry, Vol. XXXIX, No. 6, pp. 583-591.

Yost, Edward, and Wenderoth, Sondra, 1968, Additive color aerial photography: in Manual of Color Aerial Photography, J. T. Smith, Jr., and D. Anson, Editors, American Society of Photogrammetry, Falls Church, Virginia, pp. 451-471.